

## **Final Proposal-Team Lumos**

Vedant Pradeep, Shawn Reginauld, Charles Lankau, Aaron Weber, Eleanor Thomas, Dylan Diamond, Shaban Halim

### **Problem**

Approximately a quarter of the world's population lacks a reliable source of electricity. More specifically, an estimated 79% of the Third World population lacks electrical power. This equates to a staggering 1.5 billion people worldwide. In 11 out of the 47 countries in Africa, more than 90 percent of people go without electricity. In six of these -- Burundi, Chad, Central African Republic, Liberia, Rwanda and Sierra Leone -- 3 to 5 percent of people can readily obtain electric power<sup>(1)</sup>. Our team is choosing to focus specifically on Liberia. One of the more impacting implications of a lack of electrical power is an apparent scarcity of artificial light. Artificial light is an absolute necessity for any society to function and grow. Evidently the citizens of Liberia feel this way too, as they attempt to create artificial light in ways that modern society would deem both inefficient and dangerous. Many regions of Liberia are heavily reliant on the use of kerosene with a small minority using wooden torches. Both these means of light generation are inherently dangerous and each have their own set of problems. For example, kerosene lamps can pollute the room with carbon dioxide, nitrogen dioxide and sulphur dioxide. These elements are a health risk to everyone who breathes them, and are especially dangerous to pregnant women, asthma sufferers, heart patients, the elderly and young children.

For a sizable minority in Liberia, the residents do not even have the luxury of kerosene. The price of kerosene rises exponentially the further one is from urban hubs and for many people who live in remote villages, the price is simply too high. For these people, artificial lighting is simply not an option, with productivity bounded by the solar cycle. Light therefore, is a commodity. This severely cuts short the amount of time a society can be productive and severely inhibits any possible growth or improvement in these regions. Another problem to keep in mind is socio-economic tension. A vast majority of Liberia lives in abject poverty. Their GDP per capita is just over 450 USD, and their economy is still recovering from a recent civil war. Native majorities clash with immigrant minorities. Education is not being properly funded by the corrupt government to the point where a majority of young people ages 15-24 cannot read<sup>(2)</sup>. Our team is attempting to consider all these implications, and create a solution that provides a reliable means of lighting to the residents of Liberia that is both feasible to distribute, culturally sensitive and carries minimal health risks.

### **Significance of Problem**

When kerosene is burnt, it releases toxins that are harmful to an individual breathing in the flames, as well as the environment. Regardless of these risk factors, lighting is still a priority for many Liberians who do not live near access to reliable electricity, and they will continue to produce it by whatever means are available to them. As of now, their options are generally limited to the gas-burning lamps which are incredibly inefficient. They provide very little lumens for the cost. Reading with a kerosene light is incredibly taxing on the eyes and in many cases simply impossible. By attempting to solve this problem and providing aid to these people we would hope to improve the conditions of Liberians in terms of health as well as provide a base for

increased education. The reason why society utilizes artificial light is so that we can carry on with our daily lives in the absence of natural sunlight; light is the catalyst that allows work and productivity to commence. Take it away, and we are left with little choice but to cease all work and wait for daylight. If we could somehow change light from being a variable to a constant in Liberia, the sheer productivity increase would be astounding. Children could study and continue school work at night, professionals could conduct research, construction could continue past daylight hours etc. By adding an extra hour of light to the working day, overall productivity increases on average of 23%. Hopefully this addition to the average Liberian lifestyle would increase the quality of life.

## **Stakeholders**

From the perspective of a Westerner, the problem of not having access to easy and safe lighting seems huge. We rely on light and electricity for almost everything we do and cannot imagine life without it. However, to citizens of Liberia who have lived their whole lives relying only on the light from an open-flame lamp, it may not seem like that big of an issue. Liberians have a lot of other problems to worry about, such as unemployment, drug addiction and the possibility of more civil unrest. On the other hand, the usage of kerosene lamps is a problem that could be relatively easy to solve and switching to another source could improve many different aspects of their lives in ways they (and our team) would not foresee. An example could be a family with young children who want to go to school but have to work and do not have time during the day to study. They study by night with a kerosene lamp but it can only be on in the house for an hour because of the toxic fumes it emits. If the kerosene were to be replaced by another, cleaner fuel, they could study for longer and not risk their health.

Since kerosene is so widely used, there is a large market for it, with 500-1000 barrels of kerosene being consumed a day across the country<sup>(5)</sup>. Reducing or eliminating the use of kerosene would have a huge impact on Liberia's economy and change the lives of many. Kerosene distributors would be negatively impacted by this change and would have to find a different source of income. However, the introduction of bioethanol could possibly replace this market. Our team is still considering the possibility of partnering with Kiva which is an organization that supports local businesses in third world countries. Through Kiva we would reach out to small business owners in Liberia and ask them if they would ever produce and sell our product, if it was successful.

The World Health Organization is also against kerosene lighting because of the health risks related to the toxic fumes the lamps produce<sup>(2)</sup>. To combat kerosene lighting, the WHO has begun to analyze the individual fuels and set air quality guidelines for combustible fuels in order to provide health-based feedback on the sustainability and the cleanliness of utilizing such fuels. WHO is also offering to go to specific countries in order to analyze the composition of fuels to provide relative feedback based on the health/safety aspects of utilizing such fuels.

A last stakeholder is the Liberian government. Their support or lack thereof could strongly influence our project. If Liberian lifestyle changes in any way, the government would adapt to it. If our solution is to be implemented in the long term and affect as many people as we hope it can, we need the Liberian government to be on board.

## **Previous Solutions**

There have been several ideas to aid individuals without access to reliable light sources. One of the most prominent of these is named the Gravity Light and is intended to go on the market later this year<sup>(6)</sup>. The device uses gravitational potential energy to power a light source for short periods of time. This device however, only generates about a tenth of a watt of power and provides anywhere from 5-15 lumens of light. The twenty five kilogram counter-weight on the light source has to be reset every half hour. The lumens it produces furthermore, are only enough to provide a small reading area much like a flashlight. Due to cultural stigmas as well, the sterile LED lighting would seem ingenuous compared to the warm glow of kerosene lamps.

Piezoelectrics is another topic that is being considered. It is a new technology that utilizes the compression of solid crystals to create an electric current<sup>(3)</sup>. With current available crystals, the systems are not efficient at small scales. The output of the electricity is off by the power of ten when considered in daily motion such as walking. It is also possible that these crystals would have a high resale value and could be scrapped to sell on the market<sup>(7)</sup>. Solar is one of the most exciting fields and is being rapidly being deployed to countries within Africa. That being said it is also expensive and there exists a large market for resold solar panels. Furthermore, solar panels often require a way of storing electricity which means a battery is involved. This can become even more expensive, not to mention that there is also a market for selling batteries. Another solution being explored is the use of photoluminescent phosphors embedded in roofing material or some other sort of panel, perhaps one that is mobile. There is no shortage of high-intensity sunlight during the long days in West Africa. Long-persistence phosphorescent materials such as strontium aluminate may be a viable method of storing and releasing light, according to our interviews.

## **Why is this still a problem?**

Many efforts have been made in Africa to distribute goods and charity products. Liberia is one of the main targets for these humanitarian relief efforts, and as such, receives a lot of care packages and goods. When our team initially started to research the topic of lighting in rural areas, we were convinced that the solution must be a tangible device or means to create light. Our solution uses a non-alien, easy to understand technology to avoid having the same effect as other humanitarian efforts.. Recently however, we had the pleasure of speaking with Mr. Peter Dicampo, a photographer who has been on the ground in areas such as Ghana and Liberia where a reliable lighting infrastructure is not established. He told us that a lot of these areas have access to solar panel lighting devices already; they just simply aren't using them. At this point, our team re-evaluated our thinking about the problem space and decided to look more closely at some of the underlying social and cultural factors that may be responsible for this phenomena. We also decided to hone in on Liberia due to several key factors in their society such as: a lack of electricity, a corrupt and inefficient government, a rural and underdeveloped economy, and an abundance of natural resources<sup>(1)</sup>. The data we found actually showed us just how deep-seeded and intricate this problem really is. What we discovered was that a lot of these villages in Liberia place little emphasis on education and would rather devote resources to other things. What better

way to acquire more resources than to take apart a complicated solar device and trade it away? Basically, they regard these devices as mere tradable commodities. Our team arrived at our ethanol solution in an attempt to work within these cultural parameters.

## **Goal**

Team Lumos hopes that by implementing our solution in West Africa, the usage of kerosene may be reduced in homes and schools and replaced with bioethanol. The reduction in burning kerosene within the household will alleviate adverse health effects and reduce childhood mortality rates. Maximizing health benefits from cessation of kerosene lamp use for lighting is the primary focus of the team. Additionally, we hope to increase productivity by increasing the amount of time people are able to have these lights on in their homes (kerosene lamps can only be on so long without smelling the fumes). We are hope that our solution will help thousands of people to live longer, healthier and more productive lives free from kerosene fumes.

## **Objectives**

*Goal* - To replace kerosene as a source of light in rural Liberia with a self-sustaining, less-harmful alternative.

Replacing kerosene with a viable alternative fuel source:

- **Background:** Of all the world's countries, Liberia has some of the lowest per capita consumption of electricity while the citizens have the least access to lighting. This, combined with the poor infrastructure as a result of the recent civil war, makes Liberia one of the darkest countries in Africa. In rural Liberia, families rely on kerosene lamps and lanterns as a primary source of light. Additionally, many people also use kerosene stoves to cook their meals. Kerosene has grown to become a staple fuel source and consumes a large proportion of the monthly budget. Unfortunately for Liberians, kerosene is not only expensive and often difficult to procure in a rural environment, but the fumes given off during combustion are highly toxic and incur many health risks.
- **Methods:** First identify parts of the problems that are of the utmost importance. We collected data that showed the unburnt hydrocarbons are making people physically ill, and even limiting their lifespans. If we want to save lives we should completely eliminate this emission. One of our solutions to this has consistently been producing ethanol to replace kerosene. The next would be to propose a solution that increases the usefulness so that it might be implemented. This might be something similar to mantles which increase lumen outputs by a factor of 10. A follow up analysis could determine whether the solution is culturally appropriate. Reducing complexity as well as the resale value can prevent units from being stolen or resold. The next step would be decreasing the price of fuel creation followed by increasing the efficiency of its production.
- **Outcomes:** A decrease in both the annual mortality of Liberians from kerosene fume related illness and disease and the production of toxic byproducts would be measures of the team's success. The availability of lighting must be maintained

or improved if the team is to consider implementation of an alternative fuel a success.

- Anticipated Problems: Distribution of a physical product in a country with little infrastructure is the primary concern. The team will need to research how similar humanitarian aid products reach their intended populations. In being able to release a product as a humanitarian goal, it is important that the product is well received but also affordable. Cost can be lowered in higher production or compensated later on by donor groups such as KEVA. An additional anticipated problem is whether the device would be culturally appealing. Interviews with experts have indicated that some solutions, while effective, are ultimately not adopted for cultural reasons, such as different temperatures of lighting or unfamiliar packaging.

Find the safest viable solution that can displace Kerosene :

- Background: Considering the dangerous conditions that already exist within our problem space, we cannot afford to offer any more risk into the lives of those whom we wish to better. If we are to introduce a product it must work at a level that furthers civilian progress. Anything less than producing clear reduction in hydrocarbons is failure due to being the sole reason as to displace Kerosene because of its noxious fumes.
- Methods: The best way to approach this objective would be to analyze a variety of alternative fuels and select the safest and most stable energy source. Reducing hydrocarbon emissions is our primary objective so this will result in trying to harness more renewable resources as fuel sources.
- Outcomes: Testing will involve having to convert raw materials and extracting their sugars to create a form of renewable ethanol to burn. Figuring out the right ratios as to generate the exact amount of sugar needed to produce the potential bioethanol is essential in order to create a source of lighting that mirrors the effects of Kerosene.
- Anticipated Problems: This should be one of the most innovative parts of the solution area. It will be difficult to keep up the ideation without focusing in on one solution. Doing this could result in losing opportunities that could have risen from a sort of 'design process'. We would like to discover a solution rather than have a preconceived notion of one. Furthermore, the amount of research and experimentation required to investigate such an area will take a lot of time involving trial and error and therefore will result in many halts along the experimentation process to produce the efficient ratio of sugars needed to produce the most effective concentration of bio-ethanol.

Develop a model or virtual drawing/schematic to refine and embellish upon in order to lead to the eventual development of an operable product.

- Background: Having a prototype of a mechanism whether on paper, or a physical model, helps individuals analyze their design in order to ensure whether it could

properly/accurately fulfill its obligation as the product itself is directed to uphold. Therefore, by modeling the still, it enables our group to put our ideas coherently together in order to see if it will be able to carry out its desired function in addition to being ergonomically fitted to a person's needs for easy utilization. Furthermore, when going further into the developmental phase, models can help explain ideas to potential investors which could help increase fundraising to help jumpstart the initiative.

- Methods: By working towards initially achieving a general consensus of ideas, those ideas are soon incorporated into a rough draft/schematic as to approach the problem. Slowly, as the model, or in this case the prototype, gets embellished upon and refined in order to meet the sudden problems that arise during testing, the initial model slowly develops into the finalized product as a list of materials and steps are incorporated and taken in order to make the model more comprehensive/complete. In the creating of an alternative fuel such as ethanol there exists several steps that can differ, including refinement. Next, one of the most important steps would be to investigate different aspects of our solution. For example, to pursue bio-ethanol production, we would then have to research and learn the means as to harness and capture the sugars from the raw materials and properly utilize it as a means to produce effective bio-ethanol.
- Outcomes: The success of this part will be attributed to being able to make our still concept more comprehensive by taking into account more criteria and ergonomic considerations to ensure that the design functions accurately and effectively. Additionally, the development of a working schematic of the still enables us to be able to fundraise from investors in order to receive the necessary resources needed to actually initiate full-fledged production.
- Anticipated Problems: A majority of the problems from this objective would come from the construction of a prototype. There are many things that could go wrong from improper assembly to that of assessing incorrect criteria and therefore causing many pauses in the refinement process of the potential still. Additionally, another anticipated problem would include having the necessary resources and knowledge as to properly make good judgement upon refining the initial ideas to produce a comprehensive model.

#### Improving upon Effectiveness/Economy of the Product

- Background: After products are completed and distributed into the marketplace, manufacturers always re-evaluate their product's performance through tests such as customer satisfaction and reliability regarding carrying out its specific function in order to analyze whether the product adheres to the customer's needs effectively. The need to always improve upon an object to meet a person's needs is evident and is a vital part of every production phase in order to produce an effective comprehensive product. Additionally, by finding ways to cut costs during manufacturing, companies are able to save more profit and thus generate more revenue for themselves. Therefore, the still will be re-evaluated with regards to analyzing how effectively it was used by Liberians in order to figure out how to alter the product so that it can meet their future needs more directly and

effectively in terms of providing bio-ethanol. Furthermore, the still will also be evaluated to see if different materials could be used to make the product more structurally stable while cheaper in order to save money when creating a still and implement the excess funds into inventory.

- **Methods:** To effectively go about analyzing the consumer market for the still, customer satisfaction regarding the product will have to be taken into consideration in order to determine what parts of the still should be revamped in order to better adhere to each Liberian's needs. Thus, the new designs will be incorporated and utilized into the overall procedure for the product to ensure that each favorable aspect the Liberians' desired was upheld within the still. To cut production costs, different materials would be evaluated and experimented upon in order to test whether the new material is just as structurally stable as the past material used, while also being cheaper to implement for the overall design.
- **Outcomes:** By providing a more effective product than before, the luminosity would increase. Furthermore, by altering the still so that it fits the Liberians' needs better, the Liberians' should be able to conduct better work due to being able to use a better source of light that is more accustomed to their usage. Therefore, the Liberians would become more efficient in completing work and thus help stimulate economic growth throughout their country. The potential to cut costs would help the manufacturer save money and redirect it into other channels of humanitarian aid.
- **Anticipated Problems:** Problems that can be anticipated involve the incapability of configuring the still to each Librarian's needs and therefore an appropriate model would be created in order to meet as many of their demands as possible. Furthermore, resources would also be expended during testing in order to find cheaper material to bring down costs of production while holding similar integrity for the still. Therefore, resources would be wasted during experimentation before a cheaper material is found and able to compensate for the lost revenue and generate more profit.

## **Team Composition**

Team Lumos is currently composed of seven members: Aaron Weber, Dylan Diamond, Charles Lankau, Shaban Halim, Shawn Reginauld, Vedant Pradeep, and Eleanor Thomas. This team is filled with intelligent members with strong personalities and passions. Lumos will reach its full potential if we work together and every person's skills and qualities are valued and utilized. To do so, it is important that each members attributes are recognized and appreciated.

We have a member who has a strong policy background who is very knowledgeable on the current state of energy production means and the implications associated with these various processes. Furthermore, they understand the political implications of the problem and makes sure that the team is working within this political parameters. This member also contributes his advanced writing skills.

We have a team member who provides a lot of technical and hands-on knowledge to the team. He knows how a lot of electrical systems work from previous experience. He has played a key role in developing our proposed solution by designing the prototype itself. Not only does he have a lot of technical knowledge but he is also artistically talented and his work is essential in creating posters and writing papers.

We have a member who serves as the glue that holds the team together, who is in charge of organizing meetings and making sure that the team is working properly. Furthermore, the person is in charge of managing conflict in the group and keeping a good attitude. This person is very intelligent with regards to the cultural implications of our solution and has a broad understanding of Liberia after much research and advises the team in this area.

Early on in the process when we were unsure of how the team should proceed with the project and were experimenting with several different possible solutions such as phosphorescence and a sterling engine, a team member who is very adept at making fast decisions helped us move forward. This member is the decisive force in our moments of ambiguity.

One group member is in charge of all outside communication that the team has. He has helped set up several meetings with professors and various outside journalists that have been vital to this team's success. He also inspires the team with his creative and out-of-the-box thinking, pushing us to new levels.

This group member is also very artistically talented, putting in a lot of the work for posters and designs. He has a knack for layout and is knowledgeable in editing softwares. He also has a good understanding for how things work. This person has a calming presence that he brings to the group; he mediates discussion and keeps the group focused on our goals. All of these qualities are necessary for a good team environment and help Lumous be a well rounded team.

Our next group member contributes many innovative ideas and isn't afraid to think big. This person pushes the group forward with their creative thinking while having a good grasp on the technical aspect and feasibility. They played a key role in developing our proposed solution, coming up with the idea to replace kerosene with bioethanol.

Currently, we are in close contact with an advisor named Brent Wagner. He frequently sends us various scientific journals and is a very helpful resource when the team hits a dead end. Similarly, we are in contact with a photojournalist, Peter Dicampo, who has lived in many rural parts of west Africa and is the creator of a photo project called [Life Without Lights](#)(1). He has experience with energy poverty; he has lived in towns without any electricity and recorded life there. We also have received advice from Dr. Shannon Yee in the past on ways to create light and hope to continue with that relationship. In the future we hope to communicate with experts who are familiar with bio ethanol and the complications associated with it. With an ethanol specialist, we can better gauge the feasibility of our solution. So far, we have been looking at professors at Tech but are open to the idea of reaching out and exploring people outside of Tech.

## **Timeline**



Our first objective for the coming weeks is to categorize the problem in level of its importances. Due to the multi-faceted nature of our problem space which involves surveying the conditions in our target location and constructing of an efficient system which can be extensively used with the current infrastructure, categorization is a vital step for our team to move forward. We hope to accomplish this objective within the next week.

The next step is to tailor a solution to the conditions we hypothesize are prevalent in our target location. This will serve as a foundation for us to further build upon. However, a hypothetical model like this can only go so far. In order to completely understand and easily critique our solution, we need to construct a scale model. This is an integral and time consuming step which is crucial to our success in solving this grand challenge. We hope to get this far by Summer 2015. That's only the beginning. We then need to intensively critique and improve the efficiency and economic viability of our model. This determines the success of our project. We must thoroughly examine our solution and weigh its usefulness in our target location. We need to repeat this process till we, as a team, and our facilitators are convinced of its potential to succeed in our problem space. We hope to carry out evaluation and improvisation for the remainder of Fall 2015 and Spring 2016.

## **Budget**

The ethanol fuel is made by the Liberians, the lamps that burn the fuel are relatively cheap to make and in some cases, the current kerosene lamps being utilized can be used to burn ethanol. We anticipate that our main costs will be from the actual research and distillation process required to create the ethanol.

## **Equipment**

- Distillation equipment such as flasks, bunsen burners, wiring. This will be the bulk of our costs. (\$68)
- Lantern/Mantle (\$11.99)
- Yeast and sugar cane which are the reactants to actually cook the alcohol. (\$10)
- All prices from lab depot (10)

## **Travel**

Travel to La Jolla, California. [4] to the J. Craig Venter Institute

(subject to approval from Synthetic genomics incorporated) on June 12-13 (tentative) . Our team has decided to look into bioethanol as a source of fuel to replace kerosene to produce light in Liberia. To economize to maximize the efficiency of the production, our team has decided to look into bioengineered yeast. JCVI as a research institute is one of the pioneers in synthetic genomics and a learning trip to its research labs can gave us valuable insight into the working of

this process and feasibility. We would like to send three members of our team who are involved in the technical aspects of this project to JCVI to do the research.

#### Travel Expenses (April 12-13th)

1 Person Round trip(Hartsfield Jackson International Airport to San Diego International Airport and Back) - \$ 343 (not inclusive of taxes) [5]

3 Persons Round trip - \$ 1029 (not inclusive of taxes)

#### **Future Direction**

The future of our proposed solution is quite literally bright. If our solution proves to be both feasible and capable of being implemented we hope to create a long last impact on Liberia. For one thing, the Liberians would have access to a clean burning fuel with minimal adverse effects on health. By introducing bio-ethanol into the market, the marginal benefits of kerosene would be heavily outweighed by the benefits of ethanol. In addition to ethanol emitting significantly less toxic fumes, it is cheaper. Thus, there would be little reason to buy kerosene and eventually it would be phased out of the market if our solution is implemented on a large scale.

Furthermore, by the nature of our solution, the Liberian populace would achieve some level of autonomy over their energy needs. Since our solution involves the Liberians creating their own fuel, they become more independent over their energy market. This also means that individuals who lack the necessary means to purchase kerosene can create their own fuel, allowing an entire new social class of people to have access to lighting. Over the course of two years, the size of our project is what we hope to focus on. The nature of our project is largely distributional based. Once we finish our distillation process and ensure that lamps can burn this new ethanol, the success of our project will be based on how many people can utilize and are affected by our solution. Within two years we hope to see at least 50 people who are effectively utilizing our ethanol solution and have access to a reliable source of lighting.

Our ethanol solution requires a distillation process in which sugars from biomaterial is converted into burnable ethanol. Thus, we need a machine or means of facilitating this process. It would be immensely helpful to have a professor who is knowledgeable on mechanical engineering to make sure our process or machine is as efficient as it can be. In terms of funding this venture, as of right now, it appears that our solution doesn't require a large amount of capital. The bio ethanol will be largely produced by the Liberians and the lamps that the ethanol is burnt in are relatively inexpensive to create. We anticipate the largest cost would be the actual distillation process. As we obtain a more concrete process and cost we can determine which organizations are best suited to further our program. We think that some of the more valuable relationships that we can continue with Dr. Shannon Yee and Peter Dicampo. Dr. Yee gave us a lot of insight on the scientific nature of our problem as well as offered some possible solutions to our problem. Peter Dicampo, a photojournalist, as a lot of insight on the cultural landscape of Liberia and is useful for understanding the sociological implications of our problem.

Additionally, Dr. Ellen Zegura who makes two trips to Liberia a year for a mental health project she is working on agreed to help us find contacts in Liberia that would be beneficial to our team. As of now, we are currently researching the feasibility of our solution and drafting ways to go about implementing it.

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